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A NOTE ON THE RETENTION OF ACQUIRED CAPACITIES¹

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It is a familiar fact that aptitudes once acquired, if not indeed inherited tendencies, are weakened by lack of use. *Ex desuetudine amittuntur privilegia*, remarked Friar John to Panurge. The process may be observed at all psychological levels. Some of us may still call to mind the feeling of inadequacy with which, after a student's protracted summer of intellectual inactivity, we again faced the tasks of the laboratory and the lecture-room. It requires a few days to get one's knowledge under discipline again. In the more highly intellectual games, where the objective test of capacity is quite immediate, the necessity for constant practise is fully recognized. When, after a period of neglect, an ordinary player again resumes such pastimes as chess or whist, he is not surprised if he occasionally misses a simple combination or overlooks a not too obvious finesse; errors that are understood, and which at a former period could not have occurred. Such events as these demonstrate how relative a thing is the term "to forget." We may speak of a response as "forgotten" when it is not called up in the presence of some associative milieu that would have called it up at some previous time. But another associative milieu may still call it up, and only when this is no longer possible, is a response absolutely forgotten. Theoretically one might suppose that forgetting begins when immediate learning ceases, but there are experimental observations to indicate that this is not quite the case, there being a short period, 15 seconds or so after the stimuli, during which the effectiveness of the memory increases. The fewer and simpler associations required, the less will naturally be lost. The writer probably plays casino at least as well as when last remembering to have played it, fifteen years ago; auction bridge, not as well as two months ago.

¹ Read at a meeting of the Section of Anthropology and Psychology of the New York Academy of Sciences, February, 1913.

In the motor sphere, losses through disuse may be the product either of less adequate co-ordination, or of deterioration in the muscle. Both seem to have a part. When on the resumption of lawn tennis in the spring, one plays well for a set or so and then goes to pieces through fatigue sensations, the former factor appears to preponderate; and when it takes some moments to again get into the swing of some move with the punching bag, the latter. On the other hand, muscular fatigue is often a secondary result of inadequate co-ordinations; witness how a slight but practised woods-walker can always outlast a sturdier but less experienced companion. Comparison between the retention of intellectual and motor memories is possible with quantitative measurement; it seems also that after voluntary learning has ceased, there is more automatic *Einprägung* (of the "learning to skate in summer" type) with motor associations than with intellectual ones.

Proper mental or motor response to a situation, once learned, may through disuse, appear as practically entire loss, as partial loss, or as mere delay. In mental processes it is not easy to distinguish between the latter two, because the delay brings about changes in the general associative set in which the particular association required is more likely to arise. Partial loss is more especially a high level process, delay one of low levels. An especially pure form of this delay is seen in the decreased speed of practised simple reaction. A thousand observations with the writer during December, 1906, gave an approximate average of 105 with an m. v. of 10; 48 observations recently made at Harvard, though under different conditions of stimulation, an average of 123 and m. v. of 9.2.¹

For experimental purposes it seems more desirable to measure these decreases of functional efficiency in terms of delayed responses than in terms of lost responses. That is, to consider responses which have no likelihood of being lost under the experimental conditions, and measure the amount by which the responses have been delayed, from any cause incident to the disuse of a former practise ability. Two series of practise experiments, already described, afforded the conditions for the present observations. The first of these concerned the tapping test, the second the functions of addition and cancellation of digits.

Two subjects had taken part in the practise experiment

¹ The first of these observations was made with Professor Henmon; for the second the writer is indebted to Dr. Langfeld.

with the tapping test, but unfortunately only one remained accessible. The following table presents figures by which the gross rates for thirty seconds in the recent series may be compared with those of $5\frac{1}{2}$ years previous.²

TABLE I
NUMBER OF LAPS IN 30 SECONDS FOR 5 SUCCESSIVE SERIES DAILY AT
2' 30" INTERVALS

Series	RIGHT HAND						LEFT HAND					
	Days 1-10,		Days 21-30,		Days 1-10,		Days 1-10,		Days 21-30,		Days 1-10,	
	1907		1907		1912		1907		1907		1912	
	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.
1'	194.6	3.6	209.5	4.1	205.7	5.5	184.6	3.7	197.3	5.1	186.3	5.5
2'	195.4	4.4	213.7	3.7	208.3	5.8	183.8	4.7	202.3	3.8	189.6	4.0
3'	197.7	3.9	221.5	3.7	216.5	5.5	188.4	6.2	207.7	3.1	195.1	6.3
4'	200.8	3.1	223.6	2.2	218.8	5.8	188.9	4.5	211.9	5.5	198.3	5.6
5'	201.1	5.5	224.9	3.7	221.7	4.7	189.1	4.7	212.4	3.1	201.5	6.9
Av.	197.9	4.1	218.6	3.5	214.2	4.9	187.0	4.8	206.4	4.1	195.2	5.2

Comparing averages for ten consecutive days, there has been but a slight decrease in the efficiency acquired in the earlier experiments. The ten recent ones average not far from the last ten days' practise of 1907. A striking subsidiary fact is that the warming up phenomenon between the successive 30" series, practically absent until brought out by practise, has been in amount practically unaffected by the five years' intermission. Here the 1912 experiments are practically identical with those of 1907, even to the series showing the greatest warming up gain, the third in each hand. But while during the 1907 practise the left hand gained practically the same as the right, it has during the five intervening years lost very much more, both absolutely and relatively. Probably in a right handed person, the ordinary activities, in which it has the greater share, preserve its specially acquired capacity better than that of the less preferred hand. Finally, the variation of corresponding series on different days is distinctly greater than at any time during 1907. The effect of the 1907 practise was to reduce this variation, so that this is a practise effect that has been more than lost.

To consider the results from the standpoint of fatigue, the subjoined table gives the figures for the six successive 5" intervals of each 30" series, tabulated for the same set of data as before:

² The earlier results have been reported in this JOURNAL, XIX, 1908, 437-83.

TABLE II

NUMBER OF LAPS IN EACH OF THE SUCCESSIVE 5" INTERVALS. AVERAGE OF 50 CASES OF EACH INTERVAL, 5 FOR EACH OF TEN DAYS. THE M. V. GIVEN THE DAY TO DAY VARIATION OF THE AVERAGE OF THE 5 CASES FOR THAT DAY.

Series	RIGHT HAND						LEFT HAND					
	Days 1-10, 1907		Days 21-30, 1907		Days 1-10, 1912		Days 1-10, 1907		Days 21-30, 1907		Days 1-10, 1912	
	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.
0' - 5'	36.4	1.04	40.8	1.06	39.8	.80	34.2	1.06	38.1	.76	36.3	1.10
5' -10'	34.7	.52	38.8	.50	37.7	1.00	32.7	.79	36.1	.69	34.3	1.14
10' -15'	33.3	.60	36.5	.62	35.9	.94	31.2	.72	34.6	.54	32.4	.96
15' -20'	32.1	.59	35.1	.48	34.4	.70	30.4	.64	33.3	.50	31.2	.82
20' -25'	31.1	.54	33.9	.51	33.5	.96	29.5	.73	32.4	.56	30.2	.72
25' -30'	30.6	.32	33.4	.52	32.8	.84	28.9	.46	32.0	.58	29.7	.64

The situation is different in the two hands. The right hand, which as we just saw, has lost less, loses more in the earlier intervals than it does in the later; the left hand has its greater loss in the later ones. In consequence, while the right hand is in the 1912 experiments slightly less fatigable than at the close of the 1907, the left hand is rather more so; that is, it has lost more than the right both in respect to initial maximum and to endurance. The *f*'s express this endurance for the different groups of experiments as follows:

TABLE III

AVERAGE INDEX OF FATIGUE (*b*) FOR THE SUCCESSIVE 10 DAY PERIODS

		Days 1-10, 1907	Days 11-20, 1907	Days 21-30, 1907	Days 1-10, 1912
Rt. Hd.		89.0	88.2	87.0	87.8
Lft. Hd.		89.5	89.2	88.4	87.1

As is seen, the 1907 practise tended to increase the initial rate of this subject at the expense of his endurance; the endurance in the left hand has continued to weaken, while in the right it has been somewhat restored.

Among the most positive results of the 1907 experiments was that the later series of any given day became, as a result of practise, more immune to fatigue than the earlier. This feature is scarcely present in those of 1912, as is seen in the following table:

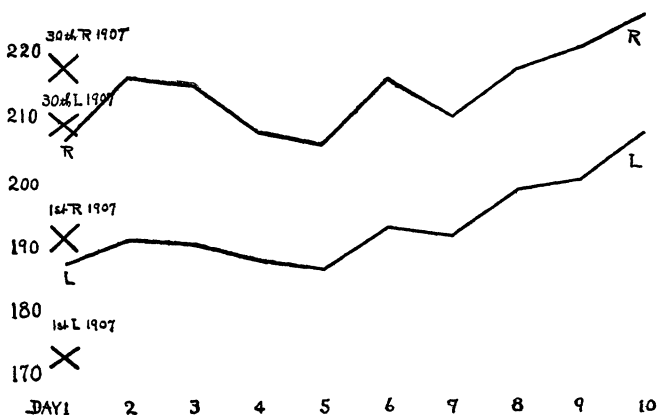
TABLE IV
AVERAGE f 's SHOWING COMPARATIVE FATIGUE EFFECTS IN THE DIFFERENT
30" SERIES

Series	RIGHT HAND						LEFT HAND					
	Days 1-10, 1907	Days 21-30, 1907	Days 1-10, 1912	Days 1-10, 1907	Days 21-30, 1907	Days 1-10, 1912	Days 1-10, 1907	Days 21-30, 1907	Days 1-10, 1912	Days 1-10, 1907	Days 21-30, 1907	Days 1-10, 1912
1	88.4	2.2	86.1	1.9	87.8	2.0	89.3	1.9	86.5	1.9	85.9	1.5
2	91.0	1.6	86.5	1.7	87.4	1.5	91.2	1.8	89.0	1.4	88.9	1.3
3	88.4	3.5	86.6	1.6	88.2	1.4	89.5	2.7	88.9	1.7	87.3	2.3
4	88.1	1.5	87.5	2.7	88.1	1.0	89.5	2.5	89.3	2.4	87.2	2.0
5	89.3	.9	87.9	1.7	87.5	1.5	88.0	3.2	88.5	1.7	85.5	2.7

What this means is that while the warming up gain of the later series of a day's experiment was in 1907 unequally distributed, being more partial to the final intervals, it is in 1912 much more equally distributed to all the 5" intervals. In 1907 the initial maximum was about the same for all five series of a day, while the endurance became better; in 1912 the initial maximum also increases from series to series, and the other intervals only in proportion to it. This, then, is another acquired property of the test that disuse has altered.

One thinks of practise as most rapid at the beginning; and one would think that on relearning an acquired but partially disused ability the gain would be especially prompt and rapid. How far this is from being the case here, is shown in the following curve:

Taps in 30"



There is no evidence of any coming gain until the 6th day; here there was a 10 days' intermission, that showed nothing abnormal. The gain now continues to the very end, and it should be mentioned that after the ninth day an acute illness caused an intermission that was prolonged to six weeks, before the final experiment.

Sensations of fatigue seem to have been more prominent in the 1912 than in the 1907 experiments. They were at first disagreeably so in the left, less marked in the right, and, as natural, decreased with the renewed practise. Their correspondence on different days with the actual fatigue conditions as indicated by f is fairly close, and seems to manifest responsiveness by reflex inhibitions to the sensations of fatigue.

The addition and cancellation tests lack the detailed precision of the tapping test, and in the present problem are subject to an additional disadvantage. The practise effect in the tapping test is relatively small, and above all quite slow. Repeated experiments on different days are therefore possible for the correction of chance variations in a single day. In the other two tests, the practise is rapid and great, so that to repeat them in their previous form involves a day to day practise that destroys the relevancy to the problem, of observations extending over different days. The efficiency of only the first day of practise renewal is to be regarded as representative of the loss by disuse. It would probably have been wiser to divide the experimental work so as to extend the tasks of one day over a period of five; this was not done, however, the experiments being repeated for two days in the same form as they had on the last day of previous practise.

The data are more significant than those of the tapping test, as six of the original ten subjects remained available for them; and an interesting point to note incidentally is that while there is everywhere a persistence of the 1910 practise, the nature of the experiment had been sometimes forgotten. A synopsis of the results is as follows:

TABLE V

Experimental Day	(1) Number of additions in 5 minutes on the 1st experimental day, January and March, 1910.	(2) Number of additions in 5 minutes on 2nd experimental day.	(30) Number of additions in 5 minutes on 30th experimental day, February and April, 1910.	(31) Number of additions in 5 minutes on 31st experimental day, December, 1912.	(32) Number of additions in 5 minutes on 32nd experimental day, December, 1912.	(30-1) Absolute gain in number of addi- tions from 1st to 30th days.	(30-31) Absolute loss from February- April, 1910, to December, 1912.	(30+1) Relative gain in number of addi- tions from 1st to 30th days (per cent. which 30th day is of 1st day.)	(30+31) Relative loss from February-April, 1910, to December, 1912.
Average of 6 subjects.	234	274	447	343	375	213	105	191	130
Their M. V.	27	28	75	43	53	54	41	22	10
Per Cent. which M.V. is of Average.....	11.5	10.2	16.8	12.5	14.2	25.4	39.1	11.5	7.7
NUMBER-CHECKING TEST. FOR THE WORDS "NUMBER OF ADDITIONS IN 5 MINUTES," ABOVE, read "AVERAGE NUMBER OF 0'S CHECKED IN 1 MINUTE, 5 CONSECUTIVE TRIALS."									
Average of 6 subjects.	56 ¹	63 ¹	107	74	80	51	33	192	145
Their M. V.	9	7	13	11	10	8	6	13	10
Per Cent. which M.V. is of Average.....	16.1	11	12.2	14.9	12.5	15.7	18.2	6.7	6.9

¹ These figures are the averages of five records made one each on the first and second five experimental days.

In the comparison of losses by disuse we meet here with the same dilemma of the absolute and relative changes. The absolute change appears the better criterion on pragmatic grounds, but both represent real aspects of the change, and both are presented. In the 1910 experiments alone one's interpretation could be somewhat guided by the consideration that the higher a subject is in the scale of practise, the more difficult it is for him to increase his performance by the same absolute amount. In the question of whether superior initial efficiency represented actual practise or practiseability, the results of the 1910 experiments³ therefore pointed to the latter conclusion. We know that the maximal ability of the 1910 experiments is the result of special practise, but at the outset of the 1912 experiments we have still to discover

³ Reported in this JOURNAL, XXIII, 1912, 75-88.

whether a person who gains much by practise loses his gain more or less readily than a person who gains but little. We should have perhaps a right to suppose that plasticity will manifest itself in negative as much as in positive directions.

In the addition test, the average drop from the end of the 1910 to the 1912 experiments is 105 units, or not quite half the absolute gain from the beginning to the end of the series of 1910. The mean variation of the 1912 experiments is distinctly less than at the close of 1910. In the absolute amount of practise gain, as well as of later disuse loss, there is much greater relative variation than in any of the daily performances among themselves. The performance at the end of practise is nearly double that at the beginning, and about a third more than that after disuse.

A weak point in the work is that no controls of the quality of vision are available for the different experiments. In one case there is positive report of a better correction of refractive errors in 1912 than obtained in the 1910 experiments. This was in the case of a subject who had shown very slow, though steady, practise effects in 1910; and the somewhat better vision in 1912 would make the loss to 1912 appear less than the fact. However, this subject actually loses on the second day of resumption instead of gaining, and in the number-checking test, the absolute gain here is less than the average.

In the number-checking test, the subjects show almost the same relative practise gain as for the addition test. The tendency to loss by disuse however, is distinctly more, the performance at the end of the 1910 practise being 145% of that at resumption, instead of 130% in the addition test. One subject has lost practically all of the 1910 gain, who had also lost more than any other of the gain in addition.

With the tapping test there is a superficial difference in the situation, for the thirtieth day of 1907 is only 26 taps or 14% ahead of the first one, while the resumption of 1912 shows a loss of 12 taps, the thirtieth day being 106% of this record. However, the disuse loss is thus some 50% of the distance from the end of practise to its beginning; so that while the changes are much less, their proportion is of the same order as the average for the addition and cancellation tests.

These observations introduce two special questions for the data. First, is a subject who gains much by practise also likely to lose much ("easy come, easy go")?

The data do not give a unified answer to this question. In the addition test the situation is fairly clear, large absolute gain going with large absolute loss to a positive correlation

of Pearson 81, that of the relative changes being 58. If the case with relieved eyestrain is excluded, the coefficients become 85 and 49 respectively. In the number-checking test, however, the presence of this case alters to 56 a coefficient that is otherwise -20, while in the relative changes a negative coefficient of -33 results from this case and that previously mentioned who lost all the gain, which was relatively little. If the former case is excluded, the coefficient is -19, if both, it is distinctly plus. It is by no means uninteresting to observe these extreme departures from the supposedly normal tendency. The probable meaning of the results is that while, when the practise curve follows a normal form, a loss by disuse may indeed be expected in proportion to the amount of practise gain, "irrelevancies" bring about anomalous forms of the practise curve in special cases, where such relationship does not appear.

A further question concerns the likelihood of a subject who loses much in one function to also lose much in the other. As measured by the Pearson coefficient, this seems to be strongly the case, more so with the absolute losses than the relative ones. In this connection it is noteworthy that if one compares the ground covered between the beginning and end of practise in the 1910 experiments, one finds a negative correlation in the improbability of the two tests, which in the relative gains is extreme. Other data do not show this negative relationship so consistently, and it is probably a good deal slighter than appears here. Still, the interesting result is reached that disuse loss is a more generalized property of the organism than practise gain. The capacity to acquire may be high for some abilities and low in others, but the tendency to forget them seems to be more equal for different abilities. The figures illustrating this point are,

Correlation between

Addition test and number checking test,	<i>r</i>
absolute practise gain	-30
absolute disuse loss	78
relative practise gain	-95
relative disuse loss	64

In sum, such observations emphasize the relativity of certain knowledge, and of memory. Pragmatically, to know a thing is to have established an association or co-ordination path which causes us to react according to it. We know a thing more certainly according as we react more certainly or in any way more effectively as though that thing were so. Though the certainty has a different source, you do not know that

two and two make four more certainly than the dervish knows the prophet's paradise awaits him on death in battle for his faith. To say that one takes a few sigma longer to add six and five than one did two years ago, is another way of saying that he does not know their sum so well; and this same lessened decisiveness of response, many times magnified, finally produces false reactions as in the method of right and wrong cases. We lose the knowledge that six and five make eleven just as we lose the knowledge of how to effectively return a service at tennis, or of how to make 230 taps in 30 seconds. Our tendency to lose in these accomplishments also appears more generalized than do our abilities to acquire them. Another feature of this sort of deterioration is its relative independence of positive interference from without, for no considerations enter to make what were the proper responses before, not the proper ones now. In this respect the work falls short, as most of experimental psychology does, of meeting the conditions of actual life, where success is a matter not simply of knowing, but of knowing the right things.